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(54) Road network navigation systems

(57) A method of coding a road network for navigation purposes comprising the step of generating a directed graph in respect of said road network, the directed graph comprising a node or vertex V1 to V10 corresponding to each of the roads R1 to R10 of the road network, and one or more weighted arcs A1-2, A2-1 etc., corresponding to each of the road junctions J1 to J4, interconnecting said nodes or vertices V1 to V10.

Fig.1.

Fig.2.

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig.1.

Fig.2.

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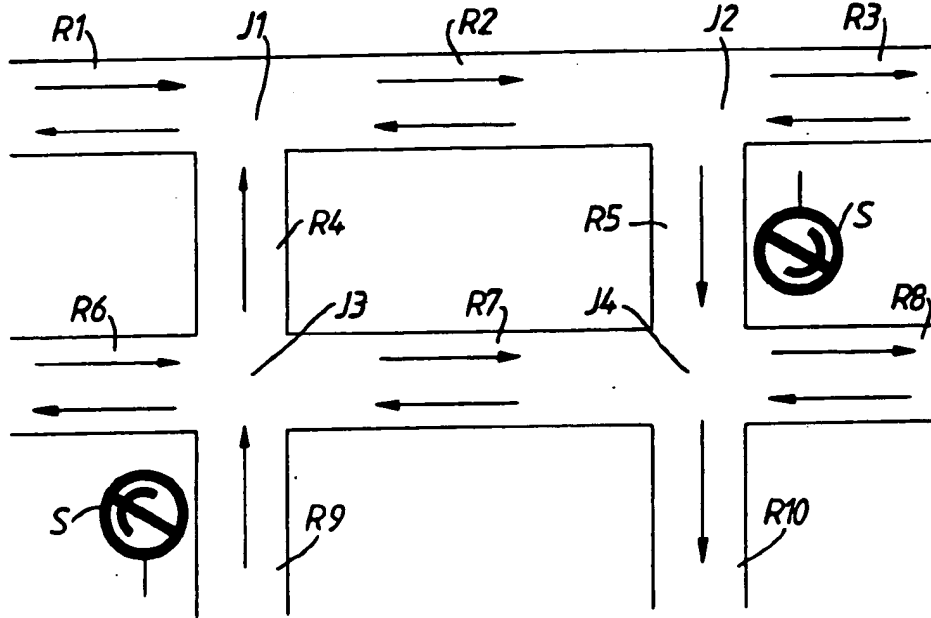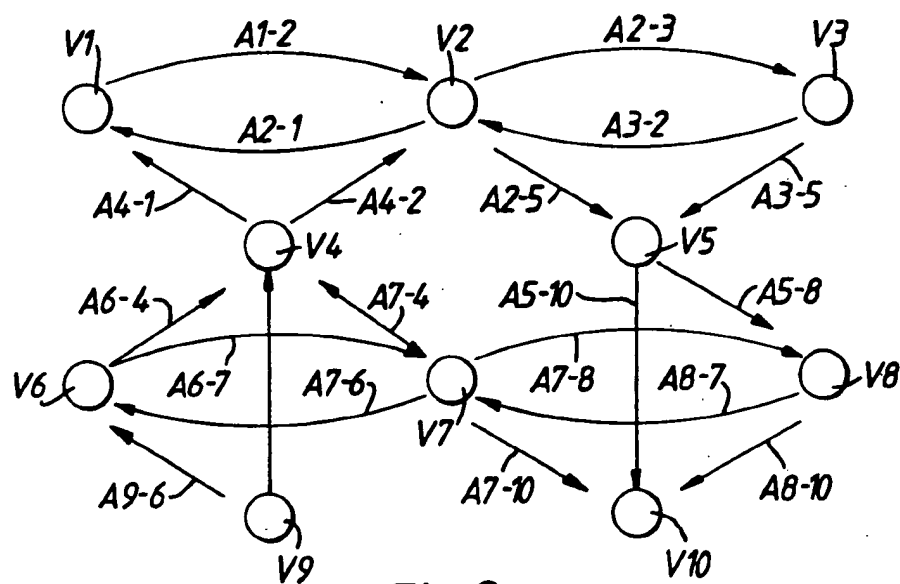## ROAD NETWORK NAVIGATION SYSTEMS

This invention relates to a method of coding a road network for navigation purposes, and to a road network navigation system incorporating such methods.

In-car route guidance systems are known in which a road network consisting of an interconnected system of roads and road junctions is coded in the form of a so-called directed graph, a minimum route search algorithm based on the directed graph being used to determine a navigation path through the road network. In such systems, the directed graph is defined as comprising a node or vertex corresponding to each of the road junctions and one or more weighted arcs corresponding to each of the roads interconnecting the road junctions. Whilst such systems are generally acceptable they cannot directly take account, for example, of travel time differences that can occur due to various turning movements, e.g. it generally takes more time to turn right than it takes to turn left, and problems related to restricted turning movements, e.g. right turns may be banned into a two-way street. The normal way of coping with these special circumstances is to store the information in say, a look-up table, which is consulted as part of the minimum route search algorithm which is used to determine a route through the road network. This necessarily requires more memory space and can increase the time required to determine the required route through the road network.

It is an object of the present invention to provide an improved method of coding a road network using directed graphs which can automatically take the above mentioned special circumstances into account.

According to one aspect of the present invention there is provided a method of coding a road network for navigation purposes comprising the step of

generating a directed graph in respect of said road network, said directed graph
comprising a node or vertex corresponding to each of the roads of said road
network, and one or more weighted arcs corresponding to each of the road
junctions of said road network interconnecting said nodes or vertices.

In a preferred arrangement for carrying out the invention according to the
aforesaid one aspect, each node or vertex is defined as being at one end of the
road to which it corresponds, and each weighted arc is defined to include an arc
portion relating to the corresponding road junction and a further arc portion
relating to a road terminating at said road junction.

According to a further aspect of the present invention there is provided a
road network navigation system comprising means for generating a directed
graph in respect of the road network in accordance with the method according
to the aforesaid one aspect of the present invention, and means for
implementing a minimum route search algorithm based on said directed graph
for determining a navigation route through said road network.

An exemplary embodiment of the invention will now be described
reference being made to the accompanying drawings, in which:

Figure 1, depicts diagrammatically a typical road network; and,

Figure 2, depicts a directed graph in accordance with the present
invention corresponding to the road network of Figure 1.

In Figure 1 there is depicted a typical road network which, for the
purposes of the present invention, is deemed to consist of four road junctions J1
to J4 and ten interconnecting roads R1 to R10. It is to be assumed that roads R1
to R3 and R6 to R8 are each two-way roads and that roads R4 and R9 are one-
way northwards and that roads R5 and R7 are one-way southwards. It is also to
be assumed that "no right-turn" restrictions apply from road R9 to road R7 and
from road R5 to road R7, as indicated by the "no right-turn" signs 5.

In Figure 2 of the drawings there is depicted a directed graph in accordance with the present invention, corresponding to the road network of Figure 1. The directed graph of Figure 2 comprises ten vertices V1 to V10 which correspond respectively to the roads R1 to R10. Adjacent ones of the vertices V1 to V10 are interconnected by weighted arcs corresponding to each of the junctions J1 to J4 and which are referenced A in combination with a hyphenated number which is indicative of the vertices that the respective arc extends between and the effective direction of the respective arc. Thus, the weighted arc which corresponds to junction J1 and which extends from vertex V1 to vertex V2 (corresponding to roads R1 to R2) is referenced A1-2, and the weighted arc which corresponds to junction J4 and which extends from vertex V5 to vertex V10 (corresponding to roads R5 to R10) is referenced A5-10. It will be appreciated, for example, that because roads R5 and R10 are one-way roads, there is only a single weighted arc (A5-10) extending between vertex V5 (corresponding to road R5) and vertex V10 (corresponding to road R10). Also, because there is a "no right-turn" restriction from road R9 to R7, there is no weighted arc from vertex V9 to vertex V7 and similarly, because there is a "no right-turn" restriction from road R5 to road R7, there is no weighted arc from vertex V9 to vertex V7. In this way road restrictions, such as restricted turning movements can be directly taken account of on the directed graph of Figure 2.

It will be appreciated that in the foregoing example, the vertices V1 to V10 correspond to the roads R1 to R10 respectively, and may be considered to exist, for example, at the mid-point of the respective road. In this case, each weighted arc A will consist of a first arc portion which corresponds to the travel time from the mid-point of one road, a second arc portion which corresponds to the travel time to traverse a junction between adjacent roads, and a third arc portion which corresponds to the travel time to the mid-point of the adjacent

road. Whilst theoretically this is acceptable, if, for example, a road becomes blocked in one direction, this will affect the weighting of at least two weighted arcs. For example, if road R2 in Figure 1 becomes blocked between junctions J1 and J2, the weighting of arcs A1-2 and A2-3 will be affected and would need to be changed in order to maintain an up-to-date weighting system.

This can be overcome by assuming that each of the vertices V1 to V10 exists at one end of their respective roads so that each weighted arc consists only of a first portion corresponding to the travel time of that road, and a second arc portion which corresponds to the travel time to traverse a junction. In this way if a particular road becomes blocked in one direction, only a single weighted arc needs to be changed. Thus, travel time changes due to different road conditions can be more easily implemented and also travel time differences due to different turning movements at the junctions J1 to J4 can be taken account of in the corresponding weighted arc.

Once a directed graph of the form of Figure 2 has been generated a computer software routine may be implemented, in known manner, in order to determine a minimum route through the road network of Figure 1. Minimum route search algorithms are known, for example, from a paper by E.W. Dykstra entitled "A note on two problems in connection with graphs", published in Numerische Mathematik 1, (1959), pages 269-271; a paper by M. Pollak and W. Wiebenson entitled "Solutions of the shortest route problem", published in Operations Research 8, 1960, pages 224-230; and from a paper by Randolf W. Hall entitled "The fastest path through a network with random time-dependent travel times" published in Transportation Science, Vol. 20, No. 3, August, 1966.

CLAIMS:

1.   A method of coding a road network for navigation purposes comprising the step of generating a directed graph in respect of said road network, said directed graph comprising a node or vertex corresponding to each of the roads of said road network, and one or more weighted arcs corresponding to each of said road junctions interconnecting said nodes or vertices.

2.   A method as claimed in claim 1, in which each node or vertex is defined as being at one end of the road to which it corresponds.

3.   A method as claimed in claim 2, in which each weighted arc is defined to include an arc portion relating to the corresponding road junction and a further arc portion relating to a road terminating at said road junction.

4.   A road network navigation system comprising means for generating a directed graph in respect of the road network in accordance with the method as claimed in claims 1 to 3, and means for implementing a minimum route search algorithm based on said directed graph for determining a navigation path through said road network.

5.   A method of coding a road network for navigation purposed substantially as hereinbefore described with reference to Figures 1 and 2 of the accompanying drawings.

6.   A road network navigation system substantially as hereinbefore described with reference to Figures 1 and 2 of the accompanying drawings.